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(54) [Title of the Invention] Drive control circuit for brushless motor

(57) [Abstract]

[Problem] To ensure stable rotary torque is produced when fluctuations in power supply voltage occur.

[Solving Means] The position where the counter electromotive force levels induced into U-phase, V-phase and W-phase drive coils from which a brushless motor 11 is constituted are equivalent is detected by means of a sensor 15 and a position detection circuit 17. When the power supply voltage supplied from a power supply 21 to the drive coils of each phase is varied with respect to a reference voltage, an inverse proportional circuit 23 outputs a phase-shift signal inversely proportional to this variation. A variable phase-shift circuit 19 outputs a switchover control signal for, in accordance with this phase-shift signal, advancing or delaying the phase with respect to the position where the counter electromotive force levels are equivalent to switch the drive current to the drive coils of each phase. A drive circuit 25 uses this switchover control signal to switchedly conduct the drive current to the drive coils.

23 INVERSE PROPORTIONAL CIRCUIT
21 POWER SUPPLY
19 VARIABLE PHASE-SHIFT CIRCUIT
25 DRIVE CIRCUIT
11 MOTOR
17 POSITION DETECTION CIRCUIT
15 SENSOR

[Claims]

[Claim 1] A drive control circuit for a brushless motor, characterized by comprising:

a position detection circuit which directly or indirectly detects a phase of a counter electromotive force induced into drive coils of a plurality of phases from which a brushless motor is configured;

an inverse proportional circuit which, when a power supply voltage supplied to said drive coils is varied with respect to a reference voltage,. outputs a phase-shift signal inversely proportional to this variation;

a variable phase-shift circuit for outputting a switchover control signal which, in accordance with said phase signal, advances or delays said detected phase to switch a drive current to said drive coils; and

a drive circuit which uses said switchover control signal to switch the drive current for driving said drive coils.

[Claim 2] Drive control circuit for a brushless motor according to claim 1, characterized in that said inverse proportional circuit is formed so as to output said phase-shift signal as a preestablished advanced phase signal when said power supply voltage is equivalent to the reference voltage.

[Detailed Description of the Invention]

[0001]

[Technical Field to which the Invention Belongs] The present invention relates to a drive control circuit for a brushless motor, and more particularly to a simple drive control circuit improved in such a way as to ensure stable motor characteristics are produced when fluctuations in power supply occur.

[0002]

[Prior Art] While not shown in the drawings, brushless motors commonly comprise, for example, a stator part formed by fixing a bearing housing that supports a bearing to a stator plate and separately winding drive coils of three phases around a stator core provided in the outer circumference of the bearing housing, and a

rotor part formed by fixing a cup-shaped rotor plate to a rotary shaft pivotally-supported by a bearing, and fixing a ring plate-shaped multi-pole rotor magnet to the inner-side wall of this rotor plate with the face of the rotor magnet opposing the tip of the stator core with a small interval.

[0003] As shown schematically in FIG. 8, the drive circuit for a brushless motor such as this is constituted from a sensor 3 disposed in close proximity of the rotor part of a motor 1 which is connected to a position detection circuit 5 to detect the position of the rotor magnet, and a drive circuit 7 which, in accordance with this position detection signal, switchedly conducts the drive current applied from a power supply (not shown in the diagram) to the motor 1.

[0004] That is to say, in accordance with a position detection signal from the position detection circuit 5, the drive circuit 7 of the motor 1 switchedly conducts (rectifies) the drive current to the Y-wired U-phase, V-phase and W-phase drive coils 9a, 9b, 9c shown in FIG. 10 at timings at which the phases are respectively displaced by 120º as shown in FIG. 9, and rotationally controls the rotor part of the motor 1.

[0005] In a brushless motor such as this, the relationship between revolutions and torque when a rated power voltage is applied to the motor 1 is expressed by line A of FIG. 11.

[0006]

[Problems to be Solved by the Invention] However, it is a characteristic of common brushless motors that, when the power supply voltage applied to the motor 1 is caused to drop for some reason or another and an undervoltage state is established, the torque and revolution speed drop proportionally therewith as expressed by line B of FIG. 11. Accordingly, actual motor design is based on satisfying predetermined motor characteristics, by way of example, on the non-load revolution speed being set somewhat higher even when the power supply voltage under

the conditions in which the motor is being used is somewhat lower than the rated voltage. That is to say, brushless motor design is based on a reduced torque constant.

[0007] Accordingly, there are concerns that when the actual applied power supply voltage is caused to rise for some reason or another and an overvoltage state is established that a higher power supply voltage as expressed by line C of FIG. 11 to be applied to the motor 1 itself and give rise to the non-optimized overspecification thereof, and that in combination with the increased current produced by the reduced torque constant, that this will generate increased heat generation or the like which is a cause of operational breakdown.

[0008] In actual motor use, the occurrence of error when a power supply apparatus is used and a drop in power supply due to power dissipation when a power supply battery is used are predictable, and a measure for dealing with such fluctuations in power supply voltage is desirable.

[0009] It is an object of the present invention, which is designed to resolve the problems of the prior art described above, to provide a drive control circuit able to produce stable motor characteristics when a drop in the power supply voltage for driving the motor occurs and which, by suppressing heat generation and so on, is similarly able to produce stable motor characteristics when a rise in the power supply voltage occurs.

[0010]

[Means to Solve the Problems] The present invention, which is designed to resolve these problems, comprises a position detection circuit which directly or indirectly detects a phase of a counter electromotive force induced into drive coils of a plurality of phases from which a brushless motor is configured;

an inverse proportional circuit which, when a power supply voltage supplied to the aforementioned drive coils

is varied with respect to a reference voltage, outputs a phase-shift signal inversely proportional to this variation;

a variable phase-shift circuit for outputting a switchover control signal which, in accordance with the aforementioned phase signal, advances or delays the aforementioned detected phase to switch a drive current to the aforementioned drive coils; and

a drive circuit which uses the aforementioned switchover control signal to switch the drive current for driving the aforementioned drive coils.

[0011] In addition, according to the present invention, the aforementioned inverse proportional circuit is formed in such a way as to output the aforementioned phase-shift signal as a preestablished advanced phase signal when the aforementioned power supply voltage is equivalent to the reference voltage.

[0012]

[Embodiment of the Invention] An embodiment of the present invention will be hereinafter described with reference to the drawings. FIG. 1 is a block diagram of an embodiment of a drive control circuit for a brushless motor pertaining to the present invention.

[0013] While, although not shown in the drawing, the brushless motor 11 (referred to in the drawings simply as "motor") of FIG. 1 has a similar configuration to the brushless motor of the example of the prior art and, for example, is constituted by a stator part formed by fixing a bearing housing which supports a bearing to a stator plate and separately winding drive coils of three phases around a stator core provided in the outer circumference of the bearing housing, and a rotor part formed by fixing a cup-shaped rotor plate to a rotary shaft pivotally-supported by a bearing and fixing a ring plate-shaped multi-pole rotor magnet to the inner-side wall of this rotor plate with the face of rotor magnet opposing the tip of the stator core with a small interval, the configuration thereof is not limited thereto.

[0014] The drive coils from which the brushless motor 11 is constituted are formed from, for example, Y-wired U-phase, V-phase and W-phase drive coils 13a, 13b, 13c as shown in FIG. 2.

[0015] A sensor 15 disposed in the brushless motor 11 for detecting the level of magnetization of the N-pole and S-pole of the rotor magnet when the motor is rotationally driven is connected to a position detection circuit 17.

[0016] The position detection circuit 17 indirectly detects the counter electromotive force levels induced into the drive coils 13a, 13b, 13c of each phase from the level of magnetization of the N-pole and S-pole obtained from the sensor 15.

[0017] Naturally, the position detection circuit 17 may be constituted to directly detect the levels of counter electromotive force.

[0018] FIG. 3 shows waveforms of the counter electromotive force induced into the U-phase, V-phase and W-phase drive coils 13a, 13b, 13c.

[0019] A power supply 21 of FIG. 1 constitutes a DC power supply that provides a direct current obtained by the low-voltage transformation of the power from a commercial power supply to a suitable voltage, a battery, or another known power supply for rotationally driving the motor 11, as well as actuating the circuits and so on of the present invention.

[0020] An inverse proportional circuit 23 for detecting the power supply voltage output from the power supply 21, and more particularly for detecting the power supply voltage levels applied to the drive coils 13a, 13b, 13c of the motor 11 and comparing these power supply voltage level with a predetermined reference voltage such as, for example, a preestablished rated voltage and outputting a phase-shift signal inversely proportional to the difference therebetween, is connected to a variable phase-shift circuit 19. Notably, there is preferably some latitude in the reference voltage value established.

[0021] The inverse proportional circuit 23 possesses a function for, for example, when the power supply voltage level applied from the power supply 21 to the drive coils 13a, 13b, 13c drops below the predetermined rated voltage, outputting a level signal inversely proportional to the level of this drop and larger than a reference phase-shift voltage as a phase-shift signal and, when the power supply voltage level rises above the rated voltage, outputting a level signal inversely proportional to this rise in level and smaller than the reference phase-shift signal as a phase-shift signal.
[0022] A variable phase-shift circuit 19 which, as shown in FIG. 4, outputs a switchover control signal for commutating the drive currents applied to the U-phase, V-phase and W-phase drive coils 13a, 13b, 13c as described above at timings at which the phases are displaced by 120º, is connected to a drive circuit 25.
[0023] Furthermore, the variable phase-shift circuit 19 possesses a voltage variable phase-shift function for, when the phase-shift signal level from the inverse proportional circuit 23 is higher than the output timing (rectifier angle) of the switchover control signal during rated operation, advancing the phase of the switchover control signal in response to this level (advanced angle) and outputting this to the drive circuit 25 and, when this phase-shift signal level is lower than the output timing of the switchover control signal during rated operation, delaying the phase of the switchover control signal to be output in response to this level.
[0024] That is to say, as shown in FIG. 3, the variable phase-shift circuit 19 outputs a switching control signal to the drive circuit 25 for, in accordance with the voltage level of the phase-shift signal, either advancing or delaying a rectifier angle to a position P where the counter electromotive forces at each phase overlap (are equivalent).
[0025] Notably, the relationship between phase advancement and phase delay of this switchover control

signal and torque and rotational speed will be described later.

[0026] The drive circuit 25 is formed by, for example, as shown in FIG. 2, the connection of an emitter of the transistors Q1, Q3, Q5 that have a collector connected to the plus-side of the power supply 21 to a collector of the transistors Q2, Q4, Q6, the connection of an emitter of the transistors Q2, Q4, Q6 to the minus-side of the power supply 21, the connection of a contact point between the transistors Q1 and Q2 with a start winding of the U-phase drive coil 13a, the connection of a contact point between the transistors Q3, Q4 with a start winding of the V-phase drive coil 13b, and the connection of a contact point between the transistors Q5, Q6 with a start winding of the V-phase drive coil 13c.

[0027] The drive circuit 25 possesses an additional function for, using switchover control signals from the variable phase-shift circuit 19 correspondent to the U-phase, V-phase and W-phase, selectively ON-OFF controlling the transistors Q1 to Q6 and switchedly conducting a drive current from the power supply 21 to the drive coils 13a to 13c.

[0028] The actuation of the drive control circuit of the brushless motor pertaining to the present invention will be hereinafter briefly described.

[0029] When the motor 11 is rotating, the counter electromotive forces of the U-phase, V-phase and W-phase drive coils 13a to 13c are detected by the sensor 15 and the position detection circuit 17.

[0030] As shown in FIG. 3, the position detection circuit 17, detects the U-phase, V-phase and W-phase counter electromotive forces and outputs the position timing thereof to the variable phase-shift circuit 19.

[0031] When the power supply voltage level applied to the drive coils 13a to 13c of the motor 11 from the power supply 21 is stable at, for example, the rated voltage, the inverse proportional circuit 23 outputs a predetermined reference phase-shift signal.

[0032] As shown in FIG. 3 and FIG. 4, the variable phase-shift circuit 19 outputs a switchover control signal to the drive circuit 25 at timings at which the phases are displaced by 120º matching the positions P where the U-phase, V-phase and W-phase levels of counter electromotive forces overlap.

[0033] Accordingly, the drive circuit 25 selectively ON-OFF controls the transistors Q1 to Q6 and, as shown in FIG. 5, switchedly conducts a drive current to the drive coils 13a to 13c at phase timings of 120º respectively.

[0034] An example in which, for some reason or another, the power supply voltage from the power supply 21 has dropped below the rated voltage will be hereinafter described.

[0035] When the power supply voltage from the power supply 21 drops, the inverse proportional circuit 23 outputs a phase-shift signal of a level inversely proportional therewith to the variable phase-shift circuit 19.

[0036] The variable phase-shift circuit 19 outputs a switchover control signal to the drive circuit 25 of a timing P1 and phase which, in response to the phase-shift signal level, has been advanced from the position P at which the U-phase, V-phase and W-phase counter electromotive forces overlap.

[0037] Accordingly, the drive circuit 25 uses the phase-advanced switchover control signal to selectively ON-OFF control the transistors Q1 to Q6, and switchedly conducts the drive current from the power supply 21 to the drive coils 13a to 13c at phase timings 120º respectively from the timing P1 advanced from a commutation point P during rated operation.

[0038] Conversely, when the power supply voltage from the power supply 21 rises above the rated voltage, a phase-shift signal of a level inversely proportional thereto is output from the inverse proportional circuit 23 to the variable phase-shift circuit 19, a switchover control signal of a timing P2 of a phase delayed in response to

this phase-shift signal level is output from the variable phase-shift circuit 19 to the drive circuit 25, and the drive current supplied from the power supply 21 to the drive coils 13a to 13c is switchedly conducted thereto at phases of 120º respectively from a timing P2 delayed from the commutation point P during rated voltage.

[0039] Normally, in an example in which a drive current Ia is conducted in the brushless motor 11 from, for example, the power supply 21 to the drive coil 13a, a counter electromotive force E and a resistance component Ra of the drive coil 13a may be expressed as the equivalent circuit of FIG. 6, and the following expression is established:

Counter electromotive force E = $K\phi n$

[0040] Here, the symbol K denotes the motor constant, the symbol ϕ denotes the magnetic flux, and the symbol n denotes the rotational speed and, when the phase of the drive current Ia is varied, the counter electromotive force is expressed as follows:

Counter electromotive force E = $K\phi\cos\theta n$

Here, the symbol θ denotes the rectifier angle which is "0" at the point P.

[0041] On the other hand, the voltage V of the power supply 21 is expressed as follows:

Power source voltage V = RaIa

$$= K\phi\cos\theta n + RaIa$$

[0042] This expression is expanded as follows to determine the rotational speed:

Rotational speed n = $(V-RaIa)/K\phi\cos\theta n$

[0043] It is clear from this expression that, if the power supply voltage V drops, it is sufficient to reduce "$\cos\theta$" or to advance the rectifier angle (commutation point of the drive current Ia) to maintain and prevent the rotational speed from dropping.

[0044] In addition, in FIG. 7 which shows the relationship between torque and rotational speed when the "$\cos\theta$" is varied to advance or delay the commutation point of the drive current Ia, although the

characteristics gradient when the commutation point of the drive current Ia is advanced is comparatively more steep than when commutation occurs during rated operation at the position where the counter electromotive forces are equivalent, the characteristics gradient is less server and torque drops when the commutation point of the drive current Ia is delayed.

[0045] The drive control circuit for a brushless motor of the present invention is constituted so that the counter electromotive force induced into the U-phase, V-phase and W-phase drive coils 13a, 13b, 13c from which the brushless motor 11 is formed is detected by the sensor 15 and the position detection sensor 17, so that when the power supply voltage from the power supply 21 to these drive coils 13a, 13b, 13c drops with respect to the reference voltage a phase-shift signal inversely proportional to the direction of variation is output from the inverse proportional circuit 23, so that a switching control signal for, in accordance with this phase-shift signal, advancing the phase with respect to the phase during rated voltage operation to switch the current applied to the drive coils 13a, 13b, 13c is output from the variable phase-shift circuit 19, and so that the drive circuit 25 uses this switching control signal to advance and switch the current switchover timing to the drive coils 13a, 13b, 13c.

[0046] Accordingly, when the power supply voltage from the power supply 21 drops below the rated voltage, because the motor 11 is driven in a state in which the current switchover timing to the drive coils 13a, 13b, 13c has been advanced, a rotational control which prevents reduction of torque at high rotation and is comparable to the state obtained in the rated voltage state is able to be produced.

[0047] Similarly, when the power supply voltage from the power supply 21 is higher than the rated voltage, a rotational control comparable to when a rated voltage state is supplied by the power supply can be produced by

delaying the phase of the commutation point from the phase during rated voltage operation so as to reduce the non-load rotational speed. At this time, because the torque constant is increased, the non-load current is reduced.

[0048] Accordingly, the employment of the drive control circuit of the brushless motor of the present invention is advantageous in that the need to design the brushless motor 11 in advance to operate at a higher rotational torque is eliminated whereupon, in the event that a rise in the applied power supply voltage occurs, overspecification and, in addition, an increase in heat generation are rendered unlikely.

[0049] While the description of the embodiment described above employs, for reasons of convenience, a description of a point at which the U-phase, V-phase and W-phase counter electromotive force levels overlap, that is to say, of a commutation point P, because the drive coils of common motors are subject to the effects of winding inductance or armature reaction and the like (omitted from the description), as long as the rectifier angle during rated voltage operation is set a little in advance of the commutation point P (the P1 side of FIG. 3) when the power supply voltage is equivalent to the reference voltage, the winding inductance and armature reaction effects on the drive coils can be reduced.

[0050] This example is no different to a configuration in which the phase is advanced or delayed during undervoltage operation and overvoltage operation with respect to the rated voltage operation to, for example, +15º during rated voltage operation, +30º during undervoltage operation, and 0º during overvoltage operation.

[0051] In addition, apart from a configuration in which the switching (rectifying) of the drive current as described above is sharply or digitally performed, a configuration in which, for example, the switching (rectifying) of the drive current involves a sine wave or

trapezoidal current, that is to say, it is analogally switched, may also be adopted.

[0052] Notably, in the embodiment of the present invention, the rated voltage of the power supply voltage from the power supply 21 may of course be arbitrarily set.

[0053]

[Effect of the Invention] The drive control circuit for a brushless motor pertaining to the present invention described above is advantageous in that, because it is constituted so that: the position at which the levels of counter electromotive force induced into the drive coils of a plurality of phases from which the brushless motor is constituted is detected by a position detection circuit; when the power supply voltage supplied to these drive coils varies with respect to a reference voltage, a phase-shift signal inversely proportional to the direction of this variation is output from an inverse proportional circuit; a switchover control signal for switching over the current to the drive coils at an advanced or delayed phase with respect to the aforementioned detection position is output from the variable phase-shift circuit in accordance with this phase-shift signal; and the drive circuit uses this switchover control signal to switch the current switchover timing for driving these drive coils, a stable rotational torque is able to be maintained and stable motor characteristics are able to be produced when the power supply voltage for driving the brushless motor drops and, similarly, heat generation and so on is able to be suppressed and stable motor characteristics are able to be produced even when the power supply voltage applied rises. In addition, in addition to the effects described above, a configuration in which the aforementioned inverse proportional circuit is constituted to output a preestablished advanced phase-shift signal when the power supply voltage is equivalent to the reference voltage is unlikely to be affected by

winding inductance or armature reaction of the drive coils from which the motor is constituted.

[Brief Description of the Drawings]

[FIG. 1] is a block diagram showing an embodiment of a drive control circuit for a brushless motor pertaining to the present invention;

[FIG. 2] is a circuit diagram showing the drive circuit and drive coils of FIG. 1;

[FIG. 3] is a waveform diagram of the counter electromotive forces induced into the drive coils;

[FIG. 4] is a waveform diagram of a switchover control signal for switching the drive coils;

[FIG. 5] is a waveform diagram of the drive currents conducted to the drive coils;

[FIG. 6] is a circuit diagram describing the actuation of the drive control circuit of the present invention;

[FIG. 7] is a rotational speed and torque characteristics diagram of the brushless motor driven by the drive control circuit of the present invention;

[FIG. 8] is a block diagram of a conventional drive control circuit;

[FIG. 9] is a waveform diagram of the drive currents conducted to the drive coils of FIG. 10;

[FIG. 10] is a circuit diagram of the common drive coils of a brushless motor; and

[FIG. 11] is a rotational speed and torque characteristics diagram of the brushless motor driven by the drive control circuit of the present invention.

[Explanation of Symbols]

1, 11 Brushless motor

3, 15 Sensor

5, 17 Position detection sensor

7, 25 Drive circuit

9a, 9b, 9c, 13a, 13b, 13c Drive coils

19 Variable phase-shift circuit

21 Power supply

23 Inverse proportional circuit

Q1, Q2, Q3, Q4, Q5, Q6 Transistors

[FIG. 1]

23 INVERSE PROPORTIONAL CIRCUIT

19 VARIABLE PHASE-SHIFT CIRCUIT

21 POWER SUPPLY

11 DRIVE CIRCUIT

17 POSITION DETECTION CIRCUIT

11 MOTOR

15 SENSOR

[FIG. 2]

25 DRIVE CIRCUIT

21 POWER SUPPLY

DRIVE COILS

U-PHASE

V-PHASE

W-PHASE

[FIG. 10]

DRIVE COILS

U-PHASE

V-PHASE

W-PHASE

[FIG. 4]

U-PHASE

V-PHASE

W-PHASE

[FIG. 3]

COUNTER ELECTROMOTIVE FORCE

U-PHASE

V-PHASE

W-PHASE

TIME

[FIG. 5]

U-V PHASE

V-W PHASE

W-U PHASE

[FIG. 6]

[FIG. 7]

ROTATIONAL SPEED

b DURING UNDERVOLTAGE OPERATION

c DURING OVERVOLTAGE OPERATION

a DURING RATED VOLTAGE OPERATION

[FIG. 8]

7 DRIVE CIRCUIT

1 MOTOR

3 SENSOR

5 PHASE DETECTION CIRCUIT

[FIG. 9]

U-V PHASE

V-W PHASE

W-U PHASE

[FIG. 11]

ROTATIONAL SPEED

b DURING UNDERVOLTAGE OPERATION

c DURING OVERVOLTAGE OPERATION

a DURING RATED VOLTAGE OPERATION

TORQUE